Taiwanese IT Pioneers:
Chintay Shih

Interviewed by: Ling-Fei Lin

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史欽泰口述歷史聽打/ Chintay Shih, Oral History

Ling-Fei Lin: I am Ling Fei Lin. Today is February 21st, 2011. This is part of the Taiwan Oral Historical Project of the U.S. Computer History Museum. [As part of that project,] we will interview several pioneers from the semiconductor and computer industries in Taiwan. Our guest today is Chintay Shih. Mr. Shih, can you tell us your Chinese and English name please?

Chintay Shih: I'm Chintay Shih and my English name is the same.

Ling-Fei Lin: Would you please talk about your background, including your birthplace, year of birth, where you grew up, your parents, your family or childhood?

Chintay Shih: I was born in 1946 in a fishing village in Kaohsiung, in the Southern part of Taiwan. My father used to work for Taiwan Sugar Corporation. He mostly worked with sugarcane farmers in the farms. Therefore I had been to many different sugarcane farms with him. Only a few families lived in the center of the farm. I grew up in a place like that. It was inconvenient to go to school and the living conditions weren't good. So by the time I reached school age, father sent me back to where I was born in the fishing village where my grandmother's house was located. I started my elementary school there.

Since my father's job required frequent relocations, I attended three different primary schools and spent two years in each school. Every time my father changed posts he'd make me transfer to another school. The last school I went to was in Madou, where there was a sugar factory as well. I grew up being independent since my parents were not always around, and I grew up in the countryside for the most part. When I was in junior high, I thought entering a higher school was important, so I studied hard to get into National Tainan First Senior High School. I finished my junior high and senior high school education there.

Meanwhile, my parents were still moving due to my father's job. By the time I was preparing for the university entrance exams, my parents had moved to Chiaotou, Kaohsiung. Owing to my outstanding performance, I didn't have to take the entrance exam. Back then, we still had the exam-free admission system, so I was admitted to NTU (National Taiwan University) without taking the exam and I moved to Taipei. This was my schooling when I was young.

Life in NTU was different from what it was like in the countryside. NTU was an open-minded school and being away from home gave me freedom. My interest in learning was quite broad [while I was] there. When I graduated from university, the economic conditions in Taiwan were not good. I graduated in 1968. Due to the economic condition in Taiwan, most university graduates who had been to good schools, would study abroad for further education, so I went abroad, too. At that time we knew little about other countries. Studying abroad for me was like visiting the Grand View Garden, the advancement of technology and living experience were stimulating. The United States was one of the most advanced countries in the world. The technology, life, and the school environment in United States were all far ahead of what they were in Taiwan, and such stimulation inspired me significantly. I made up my mind to serve people in Taiwan after graduation.

Ling-Fei Lin: What subject did you do best in school? What made you decide to major in electrical engineering?

Chintay Shih: Every student at that time had to take the university entrance exam. Students were divided into different divisions. If you were good in sciences you would choose the science division. If you were good in arts you would choose the arts division.

Ling-Fei Lin: Had the division already been started at that time?

Chintay Shih: Yes, I think it already started. I was not particularly good at any subject, but I did better at math, physics, and chemistry. At least I had more interest in them. So I was planning to choose the science division. Because I did relatively well in school, I had two options, electrical engineering and medicine. People in the southern Taiwan believed that smart people should be doctors, and that being a doctor would make one wealthy. If you wanted to study medicine you should be in division C, while people who wanted to study EE (Electrical Engineering) should be in division A. I thought about it thoroughly, and I knew that my grades might not be high enough to enter the medical department as there were so many competitors. Moreover, doctors had to stay in hospitals all the time, facing suffering patients. It sounded like no fun to me. I wanted a job that would allow me more freedom to travel around. Being a doctor made it difficult. So I chose to major in EE and ended up being in EE at NTU.

Ling-Fei Lin: Wasn't physics once people's first choice?

Chintay Shih: Yes. Was it earlier? Physics was once people's first choice, probably the one requiring the highest grades. EE was the same. They were competing against each other. I knew I was more suitable to do practical work, and EE was more related to practical things in our daily life. Physics seemed more of an academic field.

Ling-Fei Lin: You mentioned that you've studied in the U.S. Were there any differences between the education in Princeton and that in NTU?

Chintay Shih: When I was in NTU, the teaching materials were very traditional. Only scholars who returned from overseas would introduce new concepts, and open new courses. In my junior and senior years, some professors opened new courses in the department. These classes pretty much helped us determine our future careers. One was semiconductor, and the other was computer science. Both topics were new areas of study and were never taught in traditional curricula in Taiwan.

In my senior year, I met two visiting professors who had returned from overseas. The one who taught semiconductors was Fu Fang from IBM Research. He is now an academician of Academia Sinica in Taiwan. He introduced new teaching materials which were used in IBM Labs. I was not really paying attention to the other classes. It was Decision Science taught by Ruo-Cao Que. I can't remember which computer company he worked for before he taught in NTU. Those who did well in class decided to study computer science afterward. As for me, I was more into Mr. Fang's semiconductor class, so I decided to continue my studies in the field. But semiconductor-related topics were not prevalent in Taiwan so I went to the U.S. I chose Princeton because the school offered me a scholarship. If I hadn't gotten a scholarship, I would have stayed in Taiwan considering my financial condition.

Ling-Fei Lin: You said that back then these new concepts weren't taught in EE departments. So what were the traditional courses in Taiwan [at that time]?

Chintay Shih: Circuits, including electric currents, resistances, voltages, and how these are related to the design of circuits and electronic engineering…generators, motors, and things related to the logic of circuits were also included. These courses would be helpful for working in Taiwan Power Company. Traditional courses covered the telecommunication field as well, but in a more traditional realm.

Ling-Fei Lin: Didn't NCTU (National Chiao Tung University) include semiconductors in their curriculum for electrical engineering department?

Chintay Shih: In 1968, some of my classmates stayed in Taiwan after graduation. They faced limited options. One worked for the Directorate General of Telecommunications (DGT) which later became Chunghwa Telecom. The DGT had a newly established telecommunication lab that did research in the telecommunications area. Some of my classmates worked there. Another option for them was to get into the export processing industry to fabricate semiconductors and that required some EE background. For those who worked in the private sector, they were probably making home appliances, components, or hi-fi equipment. Semiconductors were rarely applied in the private sector. NCTU was one of the few universities in Taiwan that offered post-graduate programs. I think the programs were just launched at that time. Some of my classmates did go to graduate school in NCTU.

Ling-Fei Lin: Would you tell us more about your experience in Princeton?

Chintay Shih: Princeton was a leading school in academic studies. When I first arrived, I felt so lucky to have the chance to study here. The campus was beautiful, and there weren't many students or teachers. There were several fields included in my department: telecommunications, computer science, and condensed matter physics, namely semiconductors. I joined the semiconductor group studying condensed matter physics. We only had four professors, and other groups were generally the same. We had to do a lot of preparation before class. Although we were in EE, we were required to learn physics too, so we had to take courses at the Department of Physics.

Princeton's Physics [Department] was one of the best, in both the U.S. and the world, because of its neighbor, the famous Institute for Advanced Study, where Albert Einstein and other famous scholars served. Besides its good reputation, the style of teaching and examination, were very different from Taiwan where students were expected to just study hard for what the teachers taught, and passing exams was the purpose of studying.

But in the U.S., exam questions were very open-minded. It was impossible to surmise which questions would be included. The teaching style was different too. I even met a teacher, who lectured on the first chapter through the whole semester. He started with the first page and by the time the class ended, we hadn't finished the first chapter…this went on the whole semester. Then I came to realize it was the most important chapter, because it introduced concepts while other chapters could be solved by computing. They emphasized comprehension, inspiration, and independent thinking. This was very different and I believed it was the place for doing research.

Ling-Fei Lin: When did you first learn the study semiconductors? Did you begin to study them during the last two years of university?

Chintay Shih: Yes, I'd say I was inspired by Mr. Fang. There were some leading companies doing semiconductor research in the U.S. One was Bell Labs and the other one was IBM's Watson Research Center. It was a decade or so since the 1950's when semiconductors were invented, so it was still in the research stage and was not applied to daily life. It was a very new concept when I first studied it. And I felt that it would be a crucial material [in the future].

Ling-Fei Lin: What did you think about semiconductors then?

Chintay Shih: They were interesting and new. What Mr. Fang introduced was not the earliest version of bipolar transistor. It was MOS, metal–oxide–semiconductors. The structure was very simple, but it was capable of many things. We could use it for rectification and amplification. I was amazed by it, even though I did not actually see it. After I entered Princeton, I finally had a chance to do research. I studied basic physics, condensed matter physics, surface science and so forth in my Ph. D. courses. One thing special about Princeton was its location. It is close to the most important research centers on the east coast of America. It only took two hours of driving to IBM, one hour to the Bell Labs, and ten minutes to the Central Research Laboratory of RCA. Because of that, Princeton cooperated with all of those research centers, and some of the professors were closely related to them. We often had researchers from IBM and Bell Labs to talk about what they were working on in the labs, such as CCDs (Charge Coupled Devices). Back in the 60's and 70's, Bell Labs was already working on video phones. They also did projects on spaceships and outer space. Things like that were hard to imagine for us. Princeton was a place of high technology research.

Ling-Fei Lin: What was your first job? What were you in charge of? And what did you learn from that experience?

Chintay Shih: I think real jobs begin after graduation. But before graduation, I had a job that was not that important. Because I got a scholarship [to Princeton], I had to work as a teaching assistant. My job was to take care of students and the labs, similar to other school jobs. During the first summer break, my director told me that as a foreign student, we did not have many work opportunities in comparison to American students. He said if I was going back to my homeland after graduation, it would be better if I had some work experience. He was willing to arrange a summer internship for me.

As I mentioned before, there weren't many teachers and students at school. Also, because Princeton had good relationships with nearby research centers, my director introduced me to the nearby RCA's central research organization, the David Sarnoff Research Labs, for the summer, which was only a ten minute drive from school. This experience certainly enriched my knowledge, and also improved my financial condition. My scholarship was only sufficient for living, the only way to make more money was to work, and this internship was my first job. Every day I worked in the lab, helping a researcher with his experiments. I prepared samples for him, maintained facilities and equipment, got the vacuum experiments ready, settled the samples, did measurements, surveyed the data occasionally, and arranged the dates in order. During break time, I read books in the company's library. I not only gained professional experience from this summer job, but I was inspired by the company's system because the system allowed students to have an ideal environment to learn. I think it was a valuable experience. So after returning to Taiwan, I've been promoting the university-industry cooperation.

Ling-Fei Lin: What was the first job you had after graduation? Have you ever worked and studied at the same time? Any part-time job experiences in Taiwan?

Chintay Shih: I did tutoring in Taiwan for a short while, tutoring was an easy way for students to make some money.

Ling-Fei Lin: So how about your first job after graduation?

Chintay Shih: I went to the U.S. after graduation. There I had a summer part-time job when I was about to graduate. I only had to write a dissertation and the oral exam. I graduated in 1974, but I started job-hunting in 1973. I had two options at that time. One was to return to Taiwan, the other one was to work in America. The oil crisis of 1972-73 worsened the economic conditions in the United States. It was difficult to find a job then. I wrote numerous letters in 1974, probably sent out 20 or 30 resumes.

There were many new companies in Silicon Valley. Most are now closed. Those companies were hiring people to do rather practical jobs. Later I was offered two jobs. One was at the NCR in Colorado. It was a company that made computers and cash registers. The other was Burroughs in San Diego, a computer company as well. Burroughs bought a small company in San Diego to produce semiconductors. That was the reason why they were looking for semiconductor experts. Those were the opportunities I had in America.

Meanwhile, I was also searching for jobs in Taiwan. But in 1974, there weren't many openings for jobs in Taiwan due to the labor-intensive structure of industry. For those who had studied abroad and came back to Taiwan, like Mr. Fang, they'd teach at NTU, NCTU, or NTHU (National Tsing Hua University) as visiting professors for a couple years. I applied for vacancies at the three schools, and NCTU was the only one that accepted my application, but I didn't take it because the EE [school] at NTHU was teaching the traditional electrical machinery [courses], instead of microelectronic courses including semiconductor-related ones.

The school's Department of Materials Science and Engineering was still related to traditional materials science projects, like the study of metallurgy. So it wasn't the place for me. As for NTU, it was complicated. Many people were trying to get into NTU, which made it very difficult to find a job there. Nan-Hong Kuo was the Dean of NCTU. He immediately responded to my application, and said that I was welcome to teach there.

However, I was not satisfied. So I started to read the newspaper, looking for jobs. I noticed that the Directorate General of Telecommunications in Chungli was going to work on semiconductors and had started related experiments. It was the perfect job for me since at least I knew something about this field. The Directorate General of Telecommunications replied , saying that they were planning on a semiconductor project. Their adviser was in the U.S., Wen-Yuan Pan, he was at Princeton, but I didn't know him before. They suggested that I to talk to Mr. Pan, so that they'd know if I was the right person for the job.

Burroughs had offered me a job so I decided to work in the U.S. first. Since I have not passed the oral defense for the Ph. D. paper, I could not go back to Taiwan immediately. I talked to Mr. Pan when I returned to Princeton for my oral defense. That's how I started working in California. Another reason was that I wasn't familiar with practical applications. If I could work in Burroughs for a while, I'd be more confident to work in Taiwan, so I took the job in Burroughs.

Ling-Fei Lin: What have you learned from your working experience? What have you learned from your experience working for Burroughs?

Chintay Shih: Burroughs was a company that did more than research out of interest. To have sufficient semiconductor resources, it had its own semiconductor company. [Big computer] companies like this used to have semiconductor companies of their own. We thought semiconductors were the key to make progress in PCs. Computers started out with vacuum tubes that [made them] took the space of a whole room. They were capable of [doing tasks] that would seem ridiculous to us now. Later semiconductors replaced vacuum tubes. Computers became smaller and faster, they used less electricity and the memory storage became bigger.

[in the early years] computer companies owned their semiconductor companies, or at least owned a lab. Because of this, Burroughs bought a company that specialized in making semiconductors. All of the products that this company made were for Burroughs. I joined this company in 1974, when Silicon Valley had just come out with a ground-breaking invention, semiconductor memory. Before semiconductors, memories were magnetic-core memory, which were enormous. Intel began to make the 1K bit semiconductor memory chip. Its storage capability was large when compared to the magnetic-core memory.

We saw the possibilities offered by semiconductor memory, so in the Burroughs lab, we tried to develop a 4K bit, or even the next generation, the 16K bit memory chip. Our job was to continuously develop products. I learned from this experience that an enterprise needed people from different fields. It wasn't a one-person job. The company needed people to design a factory, a manufacturing department and a department that did all the testing. I realized that it was based on the collaboration between departments. This was how a company managed its business. Also, I realized a company should be of large-scale. They poured plenty of money [into our effort] for very small achievements.

I learned a lot about practical work. Of course, I also interacted with people from different fields. In addition, I [learned] basic ideas of work, scheduling, yield and business processes. I noticed that it involved a lot to produce a product. It was very different from school. At school, we had to eliminate all subordinating things to make the paper ideas workable. It was the opposite in the industry. Sometimes if you eliminated things, the product would not work. I worked there for a year and a half. What I learned most was the complexity of a company.

Ling-Fei Lin: You stayed in Burroughs until 1976 and came back to Taiwan for the RCA project. Would you like to talk about the RCA project and what did you learn from this experience?

Chintay Shih: I met Pan Wen-Yuan when I was working in Burroughs, but I knew nothing about Industrial Technology Research Institute's (ITRI) function. My connection was not to the Industrial Technology Research Institute, but to the Telecommunications Institute, and Bao-Huang Kang was the Director of this institute. While [we were in correspondence], he changed his job and retired from ITRI, and went to the Electronics Research Center as the first Director. The Director of Telecommunication Institute then became Ho Ding-Yi. Mr. Ho told me to transfer to ITRI in order to understand this project, and I became familiar with the project while working in ITRI. I came back to Taiwan in early March, 1976, and directly went to ITRI which was located at Hsinchu. My hometown was in Southern Taiwan but I went directly to Hsinchu. Honestly I knew nothing about Hsinchu. When I arrived, two people picked me up at the train station. They were Robert Tsao and Hsu Lu-Bao. Hsu Lu-Bao once worked in Philips and transferred to ITRI. They drove me to ITRI.

I came back to Taiwan in early March. A couple of days later, the government signed a contract with RCA. They had almost reached a conclusion when I came back to Taiwan, so a week after my return, the Ministry of Economic Affairs (MOEA) signed the contract [with RCA]. This project was officially launched by ITRI. I joined this project at the very beginning, and started to figure out what to do, including recruiting. This project was new to most people, only some had experience in making transistors, including the people working in Wan Bang, Kaohsiung Electronics, General Instruments or some irrelevant institutes. Some of them had no job experience while some others did.

Yang Ting-Yuan and I were more familiar with this industry. I had worked in Burroughs and Yang in Harris. So we did some preliminary preparation and provided some industry know-how, such as techniques and management knowledge for them as pre-training. In order to go abroad and to learn from RCA, we held a two-month training. Shortly after I came back to Taiwan, I went to America again at the end of April. RCA's technology transfer unit was responsible for techniques, while we purchased all the equipment and materials. They instructed us on the preparation work for example. They showed us the illustrations and we had to contact various suppliers. Each device must be purchased under government's procedures, but RCA provided the specifications. So we had to confirm with a lot of equipment suppliers.

We divided into three groups and the first one was assigned to be trained at RCA headquarters for cooperation and designing. Yang was in charge of this group. The second team was responsible for manufacturing, fab and quality control. This was assigned to me. I visited two main sites of RCA. One was in Findlay, Ohio in a remote countryside. Another site was located at West Palm Beach, Florida. So the production process group was divided into two parts. The third one was responsible for procurement and equipment testing. Chang Ching-Chu was assigned to California with two people. Some arrangements took place in the middle of the project. The core of this project was that nearly forty engineers, would learn different techniques of RCA within [a few] months to a year [timeframe]. During this period, we not only learned but also prepared ourselves to build a factory back in Taiwan.

Meanwhile in Taiwan, another group of people were also working on the project. Hu Din-hua was the leader. He had to make sure we had no problem learning in RCA, and that the work in Taiwan was going smoothly, and the plant was under construction. This went on for a year. At that time, I was in RCA headquarters first, and then I stayed in Ohio for six months. I had group members learning different skills and functions. During that time I sometimes stayed in Ohio and sometimes in Florida. I visited different equipment suppliers. I also stayed at California for a couple of weeks.

I learned a lot during the year, not only about semiconductor industry, but also how to manage a project, how to run a plant and how to organize a company. The [primary purpose] of this project was the process of learning. In terms of talented people, though there were about 30 to 40 people who were very outstanding in academics with at least a Bachelor's Degree. Most of us had Masters or Ph.D. degrees and were well-trained. However, when we were trained at RCA, it turned out that they did not need people like us, and our goals of this project were different from theirs.

While engaging in the manufacturing process, we not only learned manufacturing. Most importantly, we engaged in the most crucial part, yield improvement. Yield was a crucial point in semiconductor manufacturing. If the yield was high, costs would be low, and vice versa. It involved many things. Consequently, we need better employment with better training and knowledge to analyze problems. Though in 1970s, many things were unknown. People often had to guess whether the yield was good or not. Those engineers who joined this project and received training at RCA turned out to be the main source to solve problems. We were no longer trainees. We were able to solve problems with them, which meant we were ready to run our own business. RCA was quite generous in my view. They realized we had the potential to be their partners.

Ling-Fei Lin: You said that RCA considered you as a partner and was generous to you. But were their techniques the most advanced at that time?

Chintay Shih: Let's put it this way. We had looked for many potential partners for technology transfer. Our goal was to import technology, while cultivating our engineers simultaneously, therefore training was a large proportion of the RCA project. Many companies ignored this requirement in our proposal, or responded to us with carelessness. Usually, companies tended to sell technology only---if problem occurred, they would send people to solve the problems. This was the basic concept of technology transfer.

RCA turned out to be the one that matched with our purpose. We were not sure whether RCA had the most advanced technology, because technology advanced rapidly. RCA was a rather traditional, but sizable company, that invented many products like televisions and even LCD panels. They invented plenty of products. However, at that time they were on the downgrade. Their technologies were once world-leading, but now companies in California had surpassed them.

For example, the most advanced technology at that time was NMOS, which had faster speed and smaller size. RCA did not choose this technology. Even though they chose to develop this technology later, they gave up half way through as they found that they lacked of competitiveness. We had been pushing RCA to add NMOS technology into the project, but they canceled NMOS half way. It was difficult for us to deal with the contract issue [related to that cancellation]. Some said that RCA intentionally gave up on this project.

We found a replacement. We asked them for other replacements to compensate for our losses such as bipolar process technology. RCA had other technologies, like CMOS technology. RCA made good CMOS but no one paid attention to it. The reason why CMOS became the trend was that the technology was polished unceasingly, and it was power-saving. However, it had other drawbacks. For example, CMOS stands for complementary metal-oxide-semiconductor, which means it required devices with large areas of silicon. All these required professional judgment. RCA was a traditional yet decent company, but eventually they had to sell their technologies such as CMOS. Despite this, RCA was the most suitable company for us to do the technology transfer.

Ling-Fei Lin: Had you ever thought of applying bipolar technology at the beginning?

Chintay Shih: No, not at the beginning. NMOS was the mainstream at that time. At first we were uncertain whether NMOS was the mainstream or not. But Intel started it, and Burroughs was engaged in producing 1k and 4k memory, and soon it became the mainstream. Intel started with the 1103 with PMOS. Later they found NMOS was competitive, and people started to think that NMOS would replace other technologies.

Ling-Fei Lin: Did you consider authorizing Intel?

Chintay Shih: I guess we had asked Intel about authorization. I mentioned there were many small companies that were unable [or unwilling] to train our engineers and they were not interested in it. According to our records, we had issued 28 RFPs, but many companies turned us down.

Ling-Fei Lin: Would you like to talk more about the people who are related to the RCA's project? How was the atmosphere? Were you expected to learn the technologies to help develop our country? What do you think about the relationship between technology and the economic development of a country?

Chintay Shih: I think that there was a huge economic gap between Taiwan and America [at that time], regarding spatiotemporal background. The entire GDP of Taiwan was far less than that of IBM. As a saying goes, a company's financial position could exceed that of a country. How did they make this happen? Because I stayed in the U.S. longer, I found this project very important. For young people, they could learn more and had a promising future. Besides they would be sent abroad for training, which was attractive back then since studying abroad was not easy, especially studying in a new technology field. We were not sure how important the technology might be, or whether it would be the cornerstone of Taiwan's economy, but at least it was a hope. Plus, Mr. Sun Yun-Suan was extremely serious about this project, because during the oil crisis in 1972 or 1973, our economic growth dropped from 10 percent to 1 or 2 percent. This had never happened before and he was very anxious [about Taiwan's economic situation]. So if we did not introduce technology into our industry, the economy would be in crisis. Therefore, he invested a lot of effort on listening to scholars' and experts' opinions. Sun considered the project very important, so he established ITRI in 1973. Sun and Kwoh-Ting Li played two vital roles in making governmental policies regarding the developing technology industry. His proposal to establish ITRI [generated a lot of] controversy, as did other many technological projects.

The government's research funding was raised higher than ever. Therefore, the growth of ITRI in the 1980s was very fast because the government invested considerable amounts of money in it. I remember that before we set off in April 1976, Sun delivered a speech to us. He was the Minister of MOEA at that time, and was later became the premier of Executive Yuan. This was a huge project in MOEA. The funding was a large sum of money, though it seems relatively little now, we had US$10 million or NT$400 million for four years. We spent NT$100 million a year. Meanwhile, we were doing the Major Ten Construction Project and we spent NT$100 on building one kilometer highway. That was why I said we spent one kilometer of highway a year. The highway was 300 kilometers when completed.

We did not have sufficient funding at that time, but this was a big project and the MOEA and Sun were highly concerned. He gave us much encouragement as well as [telling us his] expectations before we departed. He had a similar background as ours. He once worked in an internship, in the Tennessee Water Conservancy Bureau, to learn electricity. After he returned to China and Taiwan, he became the most important figure in charge of our electricity construction. He shared with us his experience--- that it was important to go abroad and then to return with your findings. He hoped we could grab this chance and would succeed. I could not remember the details, the people we recruited were around 30 years old, and now they are turning 60. People at that age had little experience and were rather naïve. MOEA was a powerful department at that time; it was encouraging to have the minister come to deliver a speech to us. In 1969, there was a huge gap between Taiwan and America, so we were expected to make a success abroad, and bring our efforts back to Taiwan.

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Ling-Fei Lin: Would please talk about the relationship between [the team members of the RCA project]? And how did these people evolve within Taiwan's semiconductor industry?

Chintay Shih: I would like to introduce the leaders in the RCA project, that is Yang Ting-Yuan, Chang Ching-Chu, Hsu Chieng and I. Yang, Chang and I graduated from the same university, Princeton. We already talked about our dreams and the future at school, and we shared some similar ideas. As for Hsu, he also had the same background; each of us was in charge of a group. The most difficult part was to settle their lives there. We all had studied abroad and we had driver's licenses. This was important because apart from working, we needed to drive them and show them around. Few people had driver's licenses in Taiwan at that time, so the engineers wanted to learn how to drive as soon as they arrived, so that they could drive around on weekends. They wished to take the opportunity to travel in the U.S.

One of the craziest driving experiences was in Ohio, during a three-day long weekend when they first got their licenses. People like Fan-Cheng Tseng were very excited, and they wanted to make a round trip to Mississippi. I said they would spend all the time driving and it was not fun, but they insisted because it was a rare opportunity. Everyone learned how to drive there and some started to visit many places.

Regarding our work, we made arrangements for people to learn what they wanted by negotiating with RCA. Living was more troublesome. We lived in an apartment and people had problems with western food. We were not used to hamburgers or salad. Unlike today, we did not have McDonalds in Taiwan yet, we did not like the American food. Later they found a tolerable food, Kentucky Fried Chicken. Finally they chose to cook and buy groceries themselves, living more like the way we did in school. From then on, we were able to observe different facets [of each of these people]. Some were self-centered and only bought what they liked to eat, while some were very cooperative. Some did more work than others. People had various interests, including driving, hanging out. Some even became familiar with locals…like Chen Bi-Wan. He got along with the engineers and operators from production line. Some people would show their distinctive personalities.

Ohio was really a distant place and local residents seldom had chance to meet foreigners, especially from Asia. There was only one Asian who lived there, therefore, we also took the opportunity to do some publicity, telling them Taiwan was not Thailand and Taiwan was not a communist country. They knew nothing about Taiwan, so we introduced ourselves whenever we had the chance, including introducing Chinese and Taiwanese folk songs. It was quite interesting. I thought it was really a good chance that we could work and live together for a long period of time. Consequently, when I had the chance to arrange different [working teams], I paid attention to their compatibility and avoided putting certain people in the same group.

Ling-Fei Lin: Did you find Robert Tsao and Tseng Fan-Cheng and others outstanding at that time?

Chintay Shih: Yes, Yes, Yes. There is no doubt about that. Their outstanding talents and abilities were revealed at a very early stage. Later, when they returned to Taiwan, they all became outstanding leaders in their respective fields at that time. Robert Tsao became well-known as the president of UMC. Tseng Fan-chen's dedication to TSMC has been remarkable. I invited Chen Bi-Wan to be the General Manager of Taiwan Mask. Liu Ying-Dah was General Manager of an important business group of UMC. Huang Hsien-Hsiung is president of Wintek, and Chiu Lo-Huo is the main founder of a venture capital firm. They have all become well-known figures domestically and internationally.

Ling-Fei Lin: You mentioned the yield rate of our semiconductor demonstration plant was high. Other than having many talented personnel as you just mentioned, are there any other positive factors that might be the reason why the demonstration plant's yield was better than RCA's?

Chintay Shih: First, like I said, having many talented personnel was very important. Second, I would say confidence, because determination and self-confidence are the predictors of success. Next, it is about learning and better training. Moreover, RCA was a good partner and was willing to provide us with the information that we required and vice versa. Other than the outstanding quality of our engineers, we had hard-working operators in the production line, and most of them had graduated from junior high schools. On the site, they were more careful with numbers compared to other countries' operators. Generally speaking, we had better quality human resources, thanks to our full-fledged education system, which allowed us to perform better at work that involved numbers.

Ling-Fei Lin: You mentioned before that this RCA project is a project [in which education and] learning were very important. At that time, were there any other programs similar to this model? Or was RCA the first to provide this kind of project?

Chintay Shih: Well, according to what Minister Sun said, yes, [the RCA project] was the only project capable of delivering comprehensive learning.

Ling-Fei Lin: The only project capable of delivering comprehensive learning??

Chintay Shih: That's right. At that time, Taiwan's government was not dedicated to technology transfer at all, and technology transfer was virtually only done at the enterprise level. At the enterprise level, technology transfers were about the provision of the so-called turnkey solutions, which would be provided as a fixed solution. That means no alternations were allowed [once the contract was signed]. The turnkey solution providers would provide corresponding materials and provided remedies for their enterprise clients. Therefore, a turnkey solution does not include the most important element of technology transfer.

Technology transfer should allow new element additions, through which new solutions can be developed to solve specific problems and [the results] can be further advanced. Semiconductor technology was not standing still. The concept of technology transfer is unlike the situation where we buy a two-year technology license, and the technology would not be advanced further when the license expires. The concept of technology transfer should enable us to keep improving and come out with new ideas arising from the original technology.

Ling-Fei Lin: Did our government implement the same type of technology transfer afterwards?

Chintay Shih: Yes, but we did not see any subsequent projects with the size similar to the RCA project.

Ling-Fei Lin: You have never seen any projects with similar size after the RCA project?

Chintay Shih: Right, you can say that.

Ling-Fei Lin: In your opinion, do you think this RCA technology transfer project had anything to do with the major event where many RCA employees reported many cancer cases following the establishment of RCA factory in Taiwan?

Chintay Shih: These two events happened in different time periods. RCA set up a factory in Taiwan at a very early stage and at that time no technologies were involved and Taiwan focused more on the export industry. Many foreign companies had already set up factories in Taiwan then. Companies like Philips, General Instruments, and RCA, all founded assembly factories in Taiwan. Their factories were mainly based in Xindian and/or Nantzu Export Processing Zone. RCA entered Taiwan pretty early. Some foreign companies were involved with TV-related industries, and some were related to the semiconductor packaging industry. Back in the early days, RCA found contaminated groundwater that was a result of its waste. This was mainly due to the lack of waste regulations and management in Taiwan at that time. I don't think this event had anything to do with the RCA technology transfer project.

Ling-Fei Lin: Did this happen after the technology transfer?

Chintay Shih: These two events happened in different time periods. The event at RCA factory happened after the ITRI technology transfer project.

Ling-Fei Lin: We know that ITRI's RCA project was spun off and named UMC. Would you like to talk about that process? And how did you overcome the challenges?

Chintay Shih: I think the biggest challenge to a technology transfer is how to implement it. Because there was less knowledge about technology transfers and Taiwan's government also declared its determination to do this and also declared that enterprises must take part in this project as well. The semiconductor demonstration plant did well, better than RCA, with better cost competitiveness. This is not something that can be done in the laboratory.
The plant would be better off if a private company took over. But how? No one knew what to do then. Should we sell the whole factory or build a new one and move everything there? We had no clue. We had many debates which one was the best way. Every time we discussed the issues of the company at this stage. In the first stage from 1976 to 1980, the plant had been proven to be competitive. The next step would be to set up a bigger private enterprise based on such a plant. However, all [existing] private enterprises had very limited knowledge about the industry, were afraid of [the associated] uncertainty and risks. The government had to use preferential policies to encourage everyone to form such a company, which was later named UMC.

To establish UMC, the government made a lot of arrangements. Many government-related capital investors were persuaded to invest. Many private enterprises hesitated to invest too, setting their maximum investment share at 15%. Only a few were willing to invest more. Even if one company was willing to purchase all of the stock in this unique plant, the government would have their concerns as well.

It is very unlikely that the government would trust a person or a company to own such plant exclusively. The government thought it would be better off that everyone would own a little share of such plant. Under such paradoxical situation, UMC was founded.

Upon the establishment of UMC, our technology from RCA was not the most state-of-art technology anymore. Whether ITRI had ability to continue managing such plant and make it competitive was one question. The second question would be if such plant had only a sole investor such as ITRI, it would become another state-owned enterprise. The competitiveness of a state-owned enterprise had been a long-term issue, due to the lack of the industry supply chain. Therefore, there were two issues at that time. The first issue would be whether the demonstration plant was competitive enough to compete with others at that time and the answer was obvious and everyone knew about that. After the spin-off, whether ITRI should continue working on the project would be another crucial issue. Our government was uncertain about these issues because this had never been done before.

Finally our government decided to ask a private enterprise to take on this responsibility. It turned out that the government still held a large role in decision-making process, and ITRI was responsible for the development of related technologies. This is how UMC was established as a spin-off from ITRI. The spin-off process was relatively simple at that time. Governmental officials invited everyone to talk about what to do next. Most companies refused to be part of it and there was no controversy about that, and there were some that changed their minds halfway through and decided to quit. At that time, the government felt its responsibility was to assemble everyone, but the next problem would be how to find talented people. How to encourage talented people from ITRI to work at UMC was an issue. In addition, if there were a shortage of talented personnel in Taiwan, we would have to look for them around the world, and whether we could find them was another issue.

Mr. Du Junyuan was UMC's first director and he looked for outstanding people around the world. He failed, mainly due to Taiwan's relatively low salary level. At that time, it was rare to find people to help you start a high-tech business in a foreign country without incentives. Most of them would have to rely on a special reward system to attract talented people. At that time, everything was very difficult, including seeking investors and employees. Whether we were competitive enough to compete with others was also doubtful at that time.

Ling-Fei Lin: ITRI didn't hand over their demonstration plant to UMC, right?

Chintay Shih: No, we didn't.

Ling-Fei Lin: Why not?

Chintay Shih: I think it was because this plant was originally designed as an experimental plant. We didn’t consider how big the plant would become at first. When we introduced RCA's technology to Taiwan, the technology was used to manufacture 3-inch wafers. Like I said, technology evolves. When we introduced RCA’s technology, the technology was used to manufacture 3-inch wafers. But, RCA was already on the way to implementing a technology transfer, allowing RCA to manufacture 4-inch wafers. Technology transfer involves another risk. If you purchase a technology from a foreign company, the company was unlikely to sell the latest technology that they’re currently working on.

Ling-Fei Lin: Why didn't ITRI hand over their demonstration plant to UMC?

Chintay Shih: With the help of RCA, we started this project to build a semiconductor demonstration plant. The design was to test and verify the technology. The purposes was to verify the technology, and to know it is capable of delivering certain productivity…there were several purposes, one was to verify the technology, secondly, apart from technologies, it required [qualified] management; we needed people who knew about costs and yield rates. When the semiconductor industry was finally developed in Taiwan, we also had a talent pool. We had sufficient human resources so the ITRI R&D project might not be easily affected. Let say, there are thirty people working on a project, and the loss of twenty people to the industry would definitely crash the ITRI project because the project would not be able to continue.

There were two [other] considerations. One is that the technology we imported to Taiwan was not the most advanced technology, so there was still a lot of catching up to do. When the government invests in the R&D, they need to keep it evolving. Therefore ITRI should have an experimental plant for R&D experiments. Another reason was that for private enterprises, it would be better if the company had the ability to re-design. When we first introduced the 3-inch wafers to Taiwan, the whole world, including RCA, was working on the transfer to 4-inch wafers. From past experience, we knew such transfers were highly risky. So RCA wouldn't tell you or teach you about it, as they didn't want to take the responsibility.

Our decision was, if UMC wanted to be competitive in the future, there should be a system. We decided to build another factory that could manufacture wafers more advanced than 4-inch wafers, and that could improve on what we had learned from the old RCA factory…the arrangement of the whole factory, the design of clean rooms would be a lot better than before. We also contained the idea of transfer from the experience of working with UMC, that's why UMC was able to catch up with the world in a year. The reason behind the establishment of UMC was simple---no one wanted to invest in this industry and the government had to intervene and persuaded others to invest. Afterwards, we had had two more such cases [involving ITRI spin-outs]. One was TSMC and the other was VIS. There was a seven-year-gap between each project. Due to the differences between times and technology transfer models, we made several adjustments according to the situation at the time [of the spin-out].

Ling-Fei Lin: So then, later the demonstration plant was handed over to TSMC. And the project of VIS was different from the previous ones. Would you talk about the difference between these model factory projects?

Chintay Shih: Sure. UMC was offered a model factory. We helped them to design and build their first site in the Science Park. I remember when Mr. DingHua Hu showed me where they were going to build it in the Science Park. The whole place was grass-covered. We had to get rid of the grass to actually see the land. That was how we started there. When it came to TSMC, we had improved from 4-inch wafers to 6-inch ones. While we were building a lab for 6-inch wafers, TSMC had become a contract manufacturing foundry company and it only focused on the manufacturing. It was part of the plan to seek cooperative relationships with Philips. UMC was thus part of the first Model Factory Project. When we started the second [model factory] project, we decided to start doing technology transfers. In fact, it was Morris Chang who urged us to change direction of the project in order to make Taiwan competitive. Mr. Chang said that having the ability to compete with others was very important. He suggested that we take all of the steps at once to save time. So while we were still at the preparatory stage, we combined the stages of technology transfer, technical cooperation and transfer together. For UMC, it was merely bringing in new technology and transferring it. We later proved we were capable of designing things. The modes of these two projects were very different.

Ling-Fei Lin: So RCA transferred the technology to the ITRI first, then ITRI transferred it to UMC.

Chintay Shih: Yes, then we transferred the technology back to RCA based on our findings. The case with TSMC was that with an aim for the global market presence, we commercialized, looked for cooperative partners, and did other things at one time, which helped shorten the transfer process.

Ling-Fei Lin: Why didn't TSMC directly talk to Philips?

Chintay Shih: There was no TSMC back then. ITRI did the TSMC project by doing three things at one time.

Ling-Fei Lin: You mean ITRI started out with the idea of founding TSMC?

Chintay Shih: Yes. We were still working on the project, but Morris came and said this project was only ideal in a lab, because the whole process took too much time. Also, our technology was not advanced and we needed to seek [technology] partners. To save time, it would be better off to look for business partners, to turn the project into an investment case, and a technology transfer case, to do three things in one go.

Ling-Fei Lin: Would you tell us the correct order of what happened at that time? When did the government invite Morris to come back to Taiwan and when did he team up with ITRI for this project?

Chintay Shih: At that time, with the world changing, as well as the [semiconductor] industry, we were still trying to find the right path while working on the project. We were less known by the world then. UMC started from learning RCA technology thoroughly, and then developed from this foundation. Then the government helped the company develop in the industry. Certainly, the technology of UMC was not advanced at the global level. At that time, the company might have experienced some difficulties when competing with others in some fields, but in more advanced areas, the gap between the company and its competitors was still very wide, so ITRI kept on improving, during the second R&D phase, besides technology transfer, another important point was that, besides improving the manufacturing, we needed to work on "VLSI" design as well.

When I was doing the technology transfer with UMC, by chance I knew a person with great vision, called Carver Mead. The first time I heard about him was from Professor H. T. Kung. One summer, Professor Kung worked at the research center of Palo Alto, in Xerox Parc. Carver Mead and Lynn Conway were working on a book then. The book was called "Introduction to VLSI System." Professor Kung had contributed to one chapter of the book, and he had a copy of it before its publication. He gave me a copy as well. Certainly I couldn't understand it completely, as the thing Professor Kung worked on was parallel processing circuits. Parallel processing happened to be a part of the semiconductor studies. He gave me the book, and he told me that many people in Taiwan had difficulties understanding his work, but at least I could understand a little bit of it.

Later by chance, ITRI president Hsian-Chi Fang had a friend whose daughter was the student of Carver Mead. She knew that Taiwan was working on the project, so she suggested to her father that we should talk to Carver Mead. So we arranged for Carver Mead to visit Taiwan. I was the one showing him around when he was here. He had a good impression of Taiwan because everyone he met was playing with Rubik's Cube. He said Taiwanese people seemed intelligent. He was promoting what was called Landa Rule. He said that designing and manufacturing were two different things. The biggest challenge we had in the semiconductor industry was that with the speed of technical advancement, it was difficult to transfer to manufacturing all that we designed. Every time a new technology came out, we had to go through the design process all over again. One great thing about the semiconductor was the scaling law. It was a very important concept that he brought up in his book, and he began promoting this concept in the U.S.'s DARPA project, and in many schools.

Ling-Fei Lin: What year was it?

Chintay Shih: Around 1980, as the book came out that year. He probably had started it from his research, meaning schools were already working on it. The concept was very simple and he had promoted it in Stanford, Berkley, and in many other places. He suggested that we should have people who aren't familiar with semiconductors to design integrated circuits. If you knew about math you could do it. No one had ever had that idea before. If you knew about logic, simple logic, you could design integrated circuits. What he was saying was that software programs, so-called high-level programming, were not very related to computer hardware. As long as it was logic and flow chart, one could write any program that could be run on a computer. He said it was doable in the semiconductor field. According to him, people didn't have to be a semiconductor technology specialist to design semiconductors. It was a very important concept because training a semiconductor technology specialist required a lot of time, but programming was a job for everyone. If we could apply it to the design of semiconductors, it would be great, and we'd be able to apply it to [many] other things. But at that time, a lot of people in the United States didn't believe him. A lot of people who were working on semiconductors industry such as investors, companies like AMD, and semiconductor company CEOs believed that it was necessary to have manufacturing [wafer fabs] ability to survive in the semiconductor industry. That's why it was popular to have their own semiconductor factories among computer companies. From Burroughs, to NCR, to Honeywell, to IBM, each of them had its own semiconductor factory. However, little by little, the factories disappeared, because they were too difficult to maintain. It was related to the company's economic condition. Also, the cost of maintaining factories was causing the companies' technology to fall behind. During 1970's to 1980's when semiconductors were popular, every company would plan to buy its own semiconductor factory. That's why I thought Mead's concept was really brilliant.

Ling-Fei Lin: So, semiconductor specialists at that time were required to know about manufacturing as well?

Chintay Shih: Yes. That's why I was thrilled first time I heard about Mead's concept. I knew we were still weak, but we didn't have much burden as well as we hadn't had our own semiconductor companies yet. Also, the government wished to have many SMEs in Taiwan. It was the best to have SMEs take care of designing, because they didn't need to be big companies or have a lot of money spent on designing. From this perspective, this concept suited Taiwan well, because we had just started out. And so, while we did a technical transfer to UMC, we also used methodology in the VLSI project that consisted of structuring the design, and as a main subtopic in the research project, we called it "Common Design Center".

What is Common Design Center? It is where common resources such as design rules, design tools, cell libraries, and interface of mask were integrated to make it an interface for design and manufacturing, and this interface could be used at schools. So we encouraged professors to practice and start designing at the schools, most importantly, those student designs could be implemented at ITRI, as we had the factory make and experiment on their designs. This system helped teachers and students to realize the concept of their design. All these came out at that time.

Ling-Fei Lin: So, from what you have just mentioned, I mean Carver Mead's ideas, could we go back to the question of who was the first to bring up the idea of wafer foundry. Mr. Robert Tsao said it was his idea, but Mr. Morris Chang didn't accept his statement. Mr. Chang started TSMC and focused on wafer foundry. During his interview with us, he said that the idea came from the concept of Carver Mead and his 30-year-observation in semiconductor industry. As an onlooker, who do you think was the person that brought up the [foundry] model in both Taiwan and the world?

Chintay Shih: It's hard for me to tell that who brought it up first. This model is about the evolving of the industry, that's why I said it's important to separate design and manufacturing, from the perspective of personnel training, and the application of this model, it was meant to be this way in order to enable mass production. In other words, the foundry [model] shouldn't be the center of controversy. There were outsourcing services in Taiwan and other countries and we might include US' offshore concept.

For example, why were some products made in Southeast Asia? Many American products were made in foreign countries. It's because costs were lower overseas that outsourcing became popular. That is to say, if the products were made for the company itself, then it was offshore; if the products were made by other companies, it was a foundry such as OSE that provided electronics packaging services for other companies. Foundry was not a new concept at all. The problem is, it was a dedicated semiconductor foundry. There were people doing foundry in the 70s already. Why? It is because the investment [required to buildi] a semiconductor fab was quite large. If it wasn't supported by a big company, [building a] semiconductor fab was difficult.

The advantage of the foundry [model] was that production capacity could be shared. If a company was capable of doing this, this company could help other companies by sharing production capacity. But if the company wants to monopolize a product market, if its business is booming, this company will definitely reject other companies' requests to share its production capacity. That is the most difficult part of having semiconductor foundry services. Why would they use their best technologies to help others as it costs a lot to maintain its factories and it profits [from its own products] were high? That's why companies were against the idea of dedicated foundry. So, this Carver Mead idea was originally from the United States, especially the way they trained their specialists at school. DARPA, the US DARPA, had started a major project to allow schools working on the MOSEC project.

Robert Tsao's idea was to share production capacity through ASIC simile, it was a business idea, not a new business model, and he started with logic, which was the ASIC. So his version of foundry was to share parts of the production. In my opinion, it doesn't mean that he was giving up on designing.

Then how did it become dedicated foundry? It was not only because it was worth trying, but also because the government was trying to solve some problems. Many people from overseas had seen how successful Taiwan was and so any of them came back [to Taiwan]. These people were specialized designers, hoping to have their own semiconductor fab. They went to the government for financial help. However, the [government's] budget was limited. It had cost a lot to build one factory, and now many people, with their ability to design and abd who had concepts for products, they asked for the government to invest in their manufacturing facilities and factories. So the government saw companies like Vitelec, Quasel, and Musel, which had basic technology and products, but had no investment [to build] their manufacturing [facilities].

Ling-Fei Lin: When was this?

Chintay Shih: That was around 1984, 1985 or 1986. A lot of people from overseas joined the project. That was one thing we needed to deal with…The government was trying to deal with and solve these problems.

Ling-Fei Lin: Why did the government oppose UMC doing foundry but then allowed TSMC to start doing foundry?

Chintay Shih: I'm not sure about that. I mean, back then, whatever you were going to do in semiconductors, it would cost a lot to invest on the facilities. These were big, big investments.

Ling-Fei Lin: So you don't know why they objected to UMC's rquest at the beginning. But UMC....

Chintay Shih: UMC's technology was not in a leading position. When the Science and Technology Adviser from Executive Yuan came, he said that even ITRI's projects and technology were behind. So he suggested that the government speed up. ITRI was behind, so was UMC. So he suggested to Yun-Suan Sun that we should speed up the process. However, the government's budget was decided according to a certain procedure---there should be a discussion first, and under the best conditions there were no objections. Also, the process of changing the budget could take at least 18 months. So the adviser Bob Evans persuaded Mr. Sun to speed up all the procedures. So Mr. Sun used a reserve fund, we used the money for the development of the semiconductor and the computer [industries]. Also, according to his suggestion, there were some extra budget available for the development of the computer peripherals.

Ling-Fei Lin: Including computers, meaning...

Chintay Shih: Yes, including computer peripherals.

Ling-Fei Lin: So the government supported the industry of computer peripherals.

Chintay Shih: Yes.

Ling-Fei Lin: What was that project?

Chintay Shih: The computer peripheral project for disc and printers.

Ling-Fei Lin: Were these national projects?

Chintay Shih: Yes, these were the ITRI projects…the computer project, and the computer peripherals project. Looking back from now, these projects failed. Why? Singapore was competing for the business, and it became their major industry. As for printers, they were replaced by the electronic printers, and computer printer beat the printing machines. It's always related to the evolution of the environment and technology…and major changes like the change of industrial structure.

Ling-Fei Lin: When UMC and TSMC were founded, their technology was still behind. But within [a few] years they had caught up with the leading competitors. So would you tell us what their structure was and how they caught up with the other companies?

Chintay Shih: I didn't join any of the companies, I can only speak from my understanding. The two companies are different. As for UMC, its business strategy is quite flexible. The core business has changed [over the years]. From the original IDM [business], the company split into two parts… a design sector and a dedicated foundry. The company also invested in LCDs and other things. It was more like running an enterprise than what we had seen before. Also, when the company saw an opportunity, it developed strategic alliances with foreign partners.

TSMC was professional and persistent when it came to building a dedicated foundry business. The biggest challenge was to build a mutual trust relationship with customers, meaning that they could not to step over their customer's business. Therefore, TSMC has kept a very professional image. The company doesn't get into other fields, and it never does end products. So it may look relatively inflexible, as it must to maintain its professional image. It surely has done a great job in its field. That's why I said the two companies are different.

So, how did our technology catch up? I think reasons may vary, but it is for sure that the basic ability of Taiwan was very good. Another reason was that Taiwan had been investing in the field. Our investments were mainly focused on the semiconductor field, while other developed countries had dispersed their investments in [many] fields. Or it was because of economic conditions that they slowed down the rate of investments…in the U.S. there were only some primary industries that survived. In Japan, many big companies didn't do much investment in the 1990's. In this era of technology, the development of technology is linked to the amount of money invested in it. No investment, no improvement. Our industry's investment is one reason that our technology was able to catch up with other countries. No investment, no improvement. Plus there were our technologists. These factors made our capital market an important one. And for the technology aspect, with the training our specialists received from overseas and in Taiwan, the SOC investment, the continuous research in these fields, as well as the capital that enterprises accumulated and the [contributions of] international partners, our technology was fast improving.

Ling-Fei Lin: While you were the Director of ERSO, you accompanied Mr. Morris Chang to negotiate with Philips. That was the time when TSMC was being started. Would you like to talk about the negotiation process?

Chintay Shih: In fact, I think the negotiation process was quite long. I remember asking Mr. Chang why we were rejected as partners by many companies (except Philips, which later became an important partner [for TSMC]). In my opinion, I think it was because the Netherlands had adopted offshore strategies early on because their local market was fairly small. Offshore investment was their strategy, they were good at collaborating with the locals, and they were good at globalizing. Another reason was that they had long seen the importance of the Far East. That's the reason why they had started in Taiwan a long time ago. Also, the company had a good relationship with Mr. Guo-Ding Li, so they saw Taiwan as an important strategic partner. When TSMC brought the project to them, the reason why they decided to work with us was because they thought the Asian market was quite important. They regarded Taiwan as a very important partner. By the time they had to close their semiconductor research and development [activities], they even sold the whole semiconductor factory, which shighlighted that the semiconductor industry was indeed hard to maintain. Among all of their investments in semiconductors, I heard that

TSMC had brought them the best return on investment.

Ling-Fei Lin: What were the technologies they transferred to us?

Chintay Shih: In fact, one thing we talked about was, they had felt that the company must keep the technology for technology shares. We tried to set up restriction against this part, because the Taiwanese government had spent a lot of effort on our R&D [efforts]. We also talked about how we were going to work together to allow TSMC to be more competitive in the world. That is to say, while investing, Philips would [also] be able to help [protect] TSMC from accusations of intellectual property law violations. Also, Philips had some projects under way in the European Union. If there were more advanced technology in the future, how and what we were going to transfer were both part of the negotiations. So basically we talked about what we had in the past, and what we would have in the future. We showed them what we were capable of, while they were showing us their new technologies.

Ling-Fei Lin: Did Philips transfer 6-inch wafer manufacturing technology to TSMC?

Chintay Shih: That was our own. However, the process was quite complicated, so we sometimes had to use patented technologies or work on something that they were working on. So with this one [6 inch wafer manufacturing], we wanted to sell part of the capacity to them. Doing so, we had to provide them with what they wanted. Therefore, there were compromises.

Ling-Fei Lin: So this transfer project was different from the RCA project?

Chintay Shih: Completely different.

Ling-Fei Lin: Was it more of the turnkey solution?

Chintay Shih: It wasn't that…

Ling-Fei Lin: So comprehensive learning was not required?

Chintay Shih: No.

Ling-Fei Lin: You were learning how they made semiconductors.... And plan together....

Chintay Shih: We worked according to the need of the market and the future market. But [it was] unlike our experience with RCA; then we were starting from nothing. So the two models were very different.

Ling-Fei Lin: So it was like a jointly developed project?

Chintay Shih: Yes

Ling-Fei Lin: There's one part that I'd like to understand better. When ITRI decided to start the wafer foundry project, Mr. Morris Chang came back to Taiwan to join the project. Did ITRI have the idea of doing the project, and then invite him to come back, or did ITRI invite him first, and then the new model was decided?

Chintay Shih: Like I said, the idea came from everyone's brainstorming. ITRI had had the basic idea for the project, the idea of systemizing the design process, and how design and manufacturing were put together, that was the basic concept from Carver Mead. The important part would be whether this project could attract business opportunities or not.

Ling-Fei Lin: Were you involved in designing?

Chintay Shih: How to combine design and manufacturing involves systematic design. You need to make it a structured design methodology. Also, you will have to consider how to produce photomasks and how to integrate photomasks with manufacturing. These are concepts of systematic methodology. These were all parts of the VLSI project, but to turn the project into a [real] business was a challenge. When Mr. Chang joined us in 1985, the government was already trying to solve the problems of setting factories for those who came back from overseas. Mr. Chang said to us that what we were working on lacked international competitiveness. The only way to solve it was to make a business plan which allowed future competitiveness. So that's how we had the idea of starting TSMC.

Ling-Fei Lin: Was it because of him that you decided to....

Chintay Shih: Yes, and we had a lot of presentations until all five of Executive Yuan's ministers said yes.

Ling-Fei Lin: The development of the wafer foundry and memory industries seem to be very different. Would you tell us how ITRI started the submicron project, and how VIS came to work on DRAMs?

Chintay Shih: Let me talk about the background. These were three different events that happened over a period of more than twenty years. We spent about seven years on each project. UMC was set up in 1980, TSMC in 1987, and VIS in 1994. None of the projects were the same. In the 80's, semiconductors had just been created. Taiwan was like a virgin land for this new technology. Not many people knew about it then. After the UMC project became successful, many Chinese people, especially those from overseas invested in our projects. Overseas Chinese had better knowledge about this field, and were positive about the investment [potential]. When enough money was accumulated, we extended the idea. Also, we were about to switch the focus to designing when we had the idea of foundry. In addition to solving the problems of what overseas scholars could do, one of the biggest features was the extension of our design project, which was why Taiwan's development of the semiconductor industry was special. Our design is very strong in the world these days.

However, none of these resolved the major problems we faced. We came across two problems in the industry, one was memory, and the other was the CPU. [Designing] CPUs has probably been given up by the whole world now. Slowly new things like ARM have emerged. It was a pity we didn't do well on this project.

The second one was in the field of memory. As for memory, we all know that it is highly specialized and very costly. We were never into this part of the field until late 1980s' as the industry revived because the computer industry required large volumes of key components. At the peak, the quantity of work depended on the foreign companies' allocation. If Intel said this is the amount of CPUs that you'll be doing this year, you could probably do [only] this much work in PCs in the year. The same thing happened in the memory industry as well. It happened in 1988 and 1989, we were short of memories [globally]. Therefore, enterprises called ITRI for help, but you know, to make a product or conduct research [on a product], this could not be done in a single day, it requires a long-term R&D [investment].

In fact, ITRI at that time could do nothing to solve this problem. But in the long term, should they be concerned about this issue? Because our computer industry had been growing, people came to realize that components had begun to influence the future. That's when Stan Shih began his investment in ASM. It was probably in the 90's. ITRI had started thinking about this in the 80's. Although it was at greater risk and in need of more capital, the government was already thinking about this submicron project. But in addition to the manufacturing [process], the structure of design was [even] more important.

We also [had a] very critical [need] for the design structure. We had no experience, so we went abroad to meet the founder of Etron, Mr. Nicky Lu. His brother came to ERSO, too. He specialized in manufacturing procedures. Therefore, the designs of memory and manufacturing procedures were the main goals of the submicron project.

In 1994, this project was extended and spun out into a dedicated memory company. This project was different from the previous ones. First, the lab was not in the ITRI campus, but inside the Science Park so it could become a private company at any time. So unlike other companies it was auctioned. In short, it was the government that [developed] UMC first, then for TSMC the government found a partner from another country, and for VIS it [held an] auction. All [of the three] projects were different.

Ling-Fei Lin: So you just mentioned that it coincides with the three models. Would you tell us more about the IDM [model]?

Chintay Shih: For UMC, it was because they weren’t designing or manufacturing that they had to get involved in all fields. So they were doing things the Taiwanese and Asian markets were familiar with, like consumer electronics, electronic watches, and telephones. It happened to be the time that the production of telephones was opened in the United States. UMC started making these products.

For TSMC, there were voices asking for more design [capability], so foundry soothed the need for large amounts of capital. And there was the need to find international partners, which would help to quickly bring our technology to the world. Because the market in Taiwan was limited, the design [capability] that we had was not enough. It was necessary to solve the problems of both company size and the market [need]. Both have to be solved at the same time. As for VIS, the market need was very clear, because of the economic cycle, everyone was in need of memory, yet it required advanced technology. So the project was aiming for a certain market as it was a highly technical project. By the time the project was done, we had already caught up with the world. That’s why we used the auction [process].

Ling-Fei Lin: Why is the volatility of DRAM industry so great? And why is it so risky?

Chintay Shih: Because R&D is very important for DRAM. By this time, ITRI was not capable of catching up with it because theirs was an R&D project. R&D was so important for the industry itself. Yet the scale and R&D are great burdens for the company, as the government is no longer paying attention to this field. ITRI has changed [its focus] to some other advanced technologies, like biomedical electronics, batteries, electric cars, environmental protection, energy, and solar cells. Semiconductors are no longer the center of ITRI's R&D [investments]. Memory companies entered into a free market competition. You can see that the investment [required for]I this project was very big, and, [as a result] the number of leading companies in the world is decreasing. Now we only know of Micron in the United States, Samsung in South Korea. Even Japan is unable to keep up.

Ling-Fei Lin: The investment [required] in wafer foundries is also very huge. Why does volatility and risk of that industry seem lower?

Chintay Shih: Because foundry customers are more diversified, but memory is very specific and its design, market, and manufacturing are more integrated with each other. For the wafer foundry, the work is divided so that it is more like a platform for manufacturing.

Ling-Fei Lin: You mean there was no need to put in big investments?

Chintay Shih: The investment is big for all kinds of manufacturing. But the market is different. For a foundry, there are many partners. In fact, TSMC has made an important contribution to the world. It has made the world a more creative place by bringing the idea of design. Many companies are working on this now. So in 1994, the United States established the so-called league for designing (FSA-Fabless Semiconductor Company Association) companies that didn’t have wafer factories. It was impossible in the past, but now these are big companies.

Ling-Fei Lin: So you’re saying it’s because wafer foundry has a large number of customers that the risk is relatively low. But aren’t there many customers for DRAM, too?

Chintay Shih: But the DRAM competition is only for one aspect, and the number of products is small. For wafer foundry there are many products. Apart from manufacturing there are still issues of capacity, as well as the quality issue and the service.

Ling-Fei Lin: So for DRAM, it is because of its standardization.

Chintay Shih: It is more like standardized products.

Ling-Fei Lin: Was it because of the price [of memories] that the [business] volatility is so great?

Chintay Shih: When it gets to the so-called commodity [stage] that's true.

Ling-Fei Lin: Would you tell us about the history of ITRI? Including how it was founded. Was there a model for ITRI, like the ETRI in Korea? And how did ITRI come to have its own development model?

Chintay Shih: ITRI was founded with the help of the [Taiwanese] government. When the government first started ITRI, it was exactly the time when [1972-73] oil crisis happened. Before then, industry development was mainly focusing on traditional industries, [absorbing] excess labor from agriculture to industries. The major industries were processing, export processing, and light foundry. In early 1970's, the oil crisis impacted the textile and export industries. The government realized that it was time to start some high-tech industries, capital-intensive or technology-intensive industries. To do so, the government needed not only training [of future technology specialists] but also technology development.

Therefore, the MOEA assumed the role of leader and started promoting R&D departments. However, this R&D was more than academic research, it had to be object-oriented as well as more economic with the application of science and technology. For preparation, many people went to Korea, Japan, and the United States to observe how these countries did R&D. It was not like you said that we copied Korea's structure, because we had developed our own model. Certainly we had learned something from Korea and the United States. We are different from Battel, or ADL in America, and Kaist in Korea. Kaist itself had changed many times. It was a school for a while, and then it wasn't after some time. So the most important thing was to set up a different system. It was called the Industrial Technology Research Institute. It wasn't a completely new institute. It put three of the MOE research institutions together;. Research Center of the Electronics (ERSO) was added afterwards.

Ling-Fei Lin: The two most important industries in Taiwan are the semiconductor and the PC. What do you think the relationships are between those two industries and ITRI? Because some would say that the semiconductor [industry] seems to have been taken great care of by the government while the government seems to not care about the PC at all. What do you think?

Chintay Shih: I think both industries were different. In fact, the computer project started four years after the semiconductor project. We started two projects after the semiconductor project, one was semiconductor and the other was the computer project. So the computer industry started quite early. It was around 1979 to 1980 that we started the computer project, called the microcomputer project at that time.

Microprocessor had been introduced then. So how should we develop microprocessors? The chip itself, it belongs to the semiconductor project. But the applications of its design, such as the Chinese computer, computer peripherals, and automation, are related to computer systems. So the first phase of our computer project mainly focused on how to make Chinese computers with the help of microprocessors and their applications in automation.

The project continued for a while until multiprocessors were introduced. That was when we started the concept of minicomputers. As for Chinese computers, the biggest challenges were the input, output and the unification of Chinese coding. Many parts of them were already underway in the Institute for Information Industry (III). Back in 1979, Mr. Guo-Ding Li was not only promoting the industries, he also saw the challenges of information in society. This means that the application of computers had influenced the government, the national defense, and our livelihood a lot. So he started III with the purpose of promoting the application of information technology. He began to organize activities like Information

Month and Information Week. Information technology was thus applied to the computerization of the government, like the household registration system, customs system, and the tax system. Computers have been applied in many parts [of the Taiwanese government]. There were also the problems of industries that needed to be solved. So they started working on the Chinese computer, doing encoding and the output and input of Chinese computer. So in 1979, Mr. Guo-Ding Li established the III, and the first chief executive was Mr. Xian-Qi Fang, the president of ITRI. Therefore, ITRI and III are related.

Ling-Fei Lin: We know the government played an important role in the development of the semiconductor. What do you think is the role that ITRI played in the development of the whole PCs industry?

Chintay Shih: I can analyze that from the perspective that the computer has many dimensions. One is the applications, and the other is the design of computer systems, as well as the basic components and their contribution. As I've mentioned, the applications in government systems was driven by the III, so what did the ITRI do? ITRI was working on the hardware structure. The ITRI has also dealt with many intellectual property issues.

The development of Taiwan's computer [industry]…as we all know when it first started, there were no solid industrial goals, and industry started making electronic gaming devices. A lot of students were very into these games, so much so that the Ministry of Education and parents started to think it was a social issue, as students were less focused on their studies. So the Ministry of Education shut down all the places providing those gaming devices. This caused a problem for the industry.

Those who knew microprocessors began working on Apple PCs. Thus intellectual property rights were violated and it became a big issue. Foreign enterprises began to see Taiwan as a country that didn't respect intellectual property rights. At that time, IBM PCs had started to use an open structure. Therefore, ITRI used Microsoft and Intel as the key building blocks, and started using their software and CPU to make a new type of PC. ITRI started helping and making suggestions for those who were interested in manufacturing personal computers and IBM-compatible PCs, including the issues of software compatibility. Intellectual property rights should also be respected.

The technology of IBM PCs was continuously improving. So initially this computer was in fact quite heavy; it was not like the laptops today and it was not very portable. There were many technologies involved in the manufacturing. But with the help of ITRI, many hardware problems were solved. Also, as the computers became more compact, ITRI helped to solve problems like electromagnetic interference and heat dissipation. So ITRI helped a lot with the [development of PC] hardware.

Ling-Fei Lin: Why did ITRI have the technology to manufacture computers?

Chintay Shih: Hadn't we been having R&D projects? Those projects were to solve the problems of computer assembly. Also, in 1990, we saw that there were market opportunities for notebook PCs, so we helped 46 companies to start an alliance for notebook PC manufacturing. That alliance played a big role, which was to set up standards for the assembly of notebook PCs, so a lot of people had the chance to start professional companies that were very competitive. That was not enough. We started working on computer peripherals, disk drives, CPU, memory, etc.

Gradually, other things were being considered. As we couldn't beat Singapore in magnetic disk drives, Taiwan had started making CD-ROM drives and therefore became the leader of CD-ROM drives. That was a contribution of ITRI. ITRI has been working with the industry [also] on strategic and technical aspects. But it was not like the semiconductor industry; it didn't need a lot of money to build factory. That's why some people think the government wasn't being supportive. But I think it was the topic of division of labor and the industrial structure. For example, a lot of the memory products manufactured by Taiwan have been used in our own PC industry. Many are now used in USB flash drives. The computer industry structure itself is slowly changing. That's why our CD-ROM drives could become the best in the world.

Ling-Fei Lin: So you think that the reason why the PC industry didn't [seem to] receive much [ITRI] attention was because the capital involved was not much?

Chintay Shih: Yes, but not directly.

Ling-Fei Lin: But ITRI…

Chintay Shih: III has also helped a lot with the development of Chinese computers.

Ling-Fei Lin: So ITRI and III were quite important for the structure and other parts. However, the industry itself was the most important and influential. Do you agree to that?

Chintay Shih: It is important that the industry itself was dynamic. We need creativity in the IT industry, because many new products are invented because of such creativity.

Ling-Fei Lin: I have a question for you related to our topic. Since the PC and IC industries are very strong [in Taiwan], do you think if there's any direct relationship between these two industries?

Chintay Shih: In the past, our development was based on the need of the future global market. The result was that we had ignored the need of current global market. In this role within the global market we have always thought that we played the role as suppliers, while neglecting our part as a consumer. Some people say that Taiwan was a kingdom of manufacturing, but we lack the ability for application.

What we should do is to start taking more care of the demand end and adjusting our investments in the supply end according to demand. Otherwise we would become technology-driven, instead of demand-driven. The beginning of this concept was that we had always thought that the market in Taiwan is very small. If the market is very small, the demand for supply we'd get might be problematic. However, some countries are small, but what they do are for global needs, such as the Netherlands and Finland. Our local market being small does not mean that we can only follow the old development model. It means that we should break away from the OEM and ODM models, as the importance of local market should be re-evaluated. It means that in order to have more new models we have to take many things into consideration: for example, the issue of brand operation. In Taiwan, there are still many small companies that haven't gained attention from the global market, although there are a few [that are] known [globally]. But if we could put more effort in this, it would help a lot in the future.

Ling-Fei Lin: Another question is about the relationship between the PC and the IC industries. Do you think they are helping each other? Or do you think the development of these two industries in Taiwan is like two parallel lines?

Chintay Shih: Yes, it's not merely a PC anymore; communications is also part of it. It is now difficult to tell them apart. Nowadays, the closest relationship between a person and IT is through the mobile phone. It's not only used for connecting [with other people] but also for the Internet. The information you get from this network can be saved in different computers and put into applications. The key components thereof are semiconductors.

For example, a good logistics network is very important in the future. Products of this network are no longer called PCs. They can be equipped with sensors and can be made for communications. Some even have local computing power and even can be used to save data. Of course these things will be less and less frequent, because if you are good with communications, you can switch to cloud computing, [move] into the clouds. All of the changes in these systems or the future applications will have to do with technology integration. So the impact it has on us will get bigger and bigger.

Ling-Fei Lin: How about the past history?

Chintay Shih: There isn't much to talk about the past history, because while we were in the pursuit of industrial growth, we were devoted to the needs of the market. But we lack understanding of the market; sometimes the foreign customers would show us a model of some products and asked us to duplicate them. We did have the market but we did not really know how these products were used. I think in a certain degree this experience helped us, but in the aspect of applications, we were relatively weak as we only focused on the consumer products. Now the consumer products are more complicated. For a while the focus switched to PCs, so there are many of the computer peripherals…

Ling-Fei Lin: Taiwan has been strong in terms of PC system development and the design of PC ICs. My question is more about the relationship between these two sectors.

Chintay Shih: Yes, at the early stage we made a lot of chipsets. It started from the manufacturing of motherboards and then computers. But little by little, the market share was shrinking as it was shared by mainstream companies. So we started working on other products, like NICs, the network ICs and the control of USB flash drives. As the application [of these] is extensive, it is important to have strong design ability. Although the basic concept is to invest in manufacturing, such as [we did in the] manufacturing of semiconductors, it is the application that makes full performance of our ability. These talents can't be categorized into IT. I think in the future, services will be an important factor for the industry. A great part of a company's value will be based on services. So this will be put into consideration as well.

Ling-Fei Lin: As part of the Monte Jade Science and Technology Association, what do you think about the relationship of Taiwan's technology development with the local and overseas Chinese?

Chintay Shih: Monte Jade Association is an interesting association, because before China was opened to business opportunities, some overseas Chinese who had technological capabilities maintained frequent interactions with Taiwan. Therefore, when the development of Taiwan's technology industry began in the 1970's, some active contributors were the overseas Chinese, especially those from the innovative Silicon Valley. Under such circumstances, Monte Jade Association was founded in Silicon Valley. It started from Silicon Valley, and now it's called the West Coast Monte Jade Science and Technology Association.

Around ten years ago, we started Mount Jade Association in Taiwan. We now have 16 to 17 branches all over the world. So what is the purpose of this association? It is to build a network among the Chinese, as the first members were all Chinese. This social network is not only professional; the most important thing about it is to start entrepreneurship and invest in technology. The network of different expertise is thus built, and its results have been the most visible in Taiwan and Silicon Valley.

Now that China is developing, the investments have extended to many places in China. This is a great platform for the development of high-tech industry. With the help of their technology capital and the market, the association becomes a platform of communication. Taiwan in the past has benefited from Mount Jade. Certainly Mount Jade was not the only association devoted to it. We also received support from the government, like the Modern Engineering and Technology Seminars. Mount Jade is an informal organization. Many of the members are successful entrepreneurs, so that this platform provides a place to help young engineers or entrepreneurs.

Ling-Fei Lin: Since China has opened its market, will the overseas Chinese people's attention be drawn to China and have less interaction with Taiwan?

Chintay Shih: Yes, this is actually a trend because there are more opportunities there. But with our experience, a lot of people from the United States still remain in close connection with Taiwan. So this platform for global Chinese is now providing more room for development.

Ling-Fei Lin: Will Taiwan be marginalized?

Chintay Shih: I don't think it's likely to happen. It all depends on the role you play. If you continue the development in the technology industry, there will be more room for applications. Capital flow will be healthy, and then we don't need to worry about being marginalized.

Ling-Fei Lin: The following is a more personal question. In your career, when do you feel most proud of yourself or have the greatest sense of accomplishment?

Chintay Shih: I think I was very lucky to be able to witness and even took part in the evolution of Taiwan's technology industry. One cannot buy such experience with money. Also, as I have worked for ITRI from 1976 to 2004, I have seen how the industry, the scale of ITRI, and the policy changed. These were all very important for the change of the technology industry in the past 30 years. I was really lucky that I had met many influential figures in the industry, like Mr. Sun and Mr. Li.

Ling-Fei Lin: If there was one thing you could change in your career, what would it be?

Chintay Shih: History cannot be reversed and that's why it's interesting. We can look back at a certain period of time and see what we had decided was probably not the best decision from today's perspective. However, it's hard to say what would happen if it was done differently, because all the deciding factors were interrelated. Things might change because of other conditions. For example, if ITRI decided not to work on certain projects at the moment, the industry might agree with it. But later on, like in the case of DRAMs a couple of years ago, they were saying the government should have done something. It's hard to say what it might be like if the government had developed a policy to provide financial relief, train specialists, or carry out R&D [projects]. The role the government plays during the process of development or what the enterprise should do are hard to predict. However, I think it was a right decision that I decided to come back to Taiwan.

Ling-Fei Lin: Why didn't you join UMC? Did you ever regret not doing so?

Chintay Shih: On the one hand, I know the competition in the industry and the competition in the research sector are different. I felt that it might be more appropriate for me to stay in the research sector. It was also because that would be beyond my role if I view the development of industry as a personal goal and value, and it would violate my principles. Under this circumstance, since ITRI was a good platform for the industry, I decided to stay.

Ling-Fei Lin: So you are fonder of doing research…?

Chintay Shih: For research, there are lots of things that I can do. The job at ITRI was quite challenging for me.

Ling-Fei Lin: For those young engineers and scientists who want to contribute to the semiconductor or PC industry, what suggestions would you give them?

Chintay Shih: From my experience, I believe it is important to have a good foundation. Once you're equipped with the basic ability, you have to choose a career. I believe money and salary shouldn't be the most essential factors while choosing your career. I think it is more important for you to see the significance and the importance of your job. A lot of people in the Science Park work really hard and they've already thought about retirement while they are in their thirties and forties. Retirement should have never been an option; you should consider the meaning of work and not feel tired of it. You should think about it all thoroughly. Doing so makes work meaningful, and you will never want to run away from your job.

Ling-Fei Lin: What do you think the next big event in the semiconductor and PC industry will be? What challenges do you think it will bring?

Chintay Shih: Among the semiconductor, PC, telecommunications, and the IC industries, technology will gradually become a less important factor and be replaced by either services or applications. It is because, not only people, but everything is related to the use of the Internet, which will be the Internet of Things. The question is, why did people start working on this? And how will this be applied? It is beyond the consideration of economy. This also includes some of the biggest problems the human beings are facing: such as aging, population, climate changes, global warming, and reduction of carbon emissions. Putting all these issues into consideration allows us to think from the viewpoint of applications, from the perspective of the enterprises, economy, and government policies.

Applications can have a great influence on the technology. Take sensors for example, what are they made for? And health care can be an issue, too. Not many people have thought about its return on investment as its return is immeasurable, and which might also be reflected in a country's competitiveness. Sometimes people might wonder if the government is less and less connected to the enterprises. I personally think the government has put more and more effort into dealing with certain issues, such as health care, education, environmental issues, and so forth. As the future development of semiconductors, information, computing, and the so-called cloud computing change the business model, one important target is to find better applications, such as the smart city, energy conservation, and health care, not to mention business. It can even help with resources such as water and food. That will be the direction in the future.

END OF INTERVIEW

